Art. XXII.—*On a Proposed New Method of Weighing, applicable to the Gold Bullion Assay.*

By George Foord, Esq.

[Read 8th November, 1875.]

It is well known that the modern practice of the gold assay includes many refinements upon the routine formerly practised; that it commands chemicals of greater purity, balances of greater sensitiveness and accuracy, and certain accessory tools which facilitate and expedite the work. But it is also well understood, especially by those immediately interested in the work, that although the method has been thus refined, it still falls short of absolute certainty and exactitude, and that further progressive improvement is still possible. One of the chief sources of minor errors which may yet be in part removed is that which belongs to the operation of weighing, and it is the object of this paper to propose modifications, which promise some advantage over the method of weighing hitherto practised.

It will assist my explanation if in the first place I offer a few practical observations concerning the construction and adjustment of the assay beam.

For weighing, in the ordinary routine of the gold assay, there are required :—

1st.—A sensitive and accurate balance.

2nd.—A series of accurate weights.

The balance-beam should be as light as possible, the requisite stiffness being at the same time secured. The arms of the balance should be of exactly equal length, measuring from the centre to each end knife edge. The knife edges must be sharp. The centre of gravity should be a little below the plane of the three knife-edges, and immediately under the centre knife-edge. Each arm of the beam should be accurately and distinctly divided by lines into fifty parts, each fifth mark from the centre, however, being distinguished by a dot instead of a line; these dots will therefore indicate tenths of the space between the centre and end knife-edge. The pans, of whatever pattern, should be small and light. The scale, measuring the sweep of the index or needle, should be accurately divided, so that each division of this scale represents uniformly a subdivision of the smallest weight: for example, when the real weight of the rider is $\frac{1}{10}$ of a grain the subdivisions of the index scale should represent $\frac{1}{100}$th part of the rider weight, or ·001 of a grain.

The beam should be constructed as simply and of as few pieces of metal as possible; the *fixed* constituent members of the beam should be fastened together as firmly as possible; the movable pieces, the ball and tongue, should be fitted to move neither too stiffly nor too loosely, but so as to retain whatever position they are placed in during the adjustment and after-use of the beam.

When the skilled workman has exerted the utmost care and ability in making such a balance-beam, the instrument will require adjustment of the tongue and ball, that is to say, of the centre of gravity of the beam, so as to suit it for the special work for which it is to be used, whether for quantity of work or for extreme accuracy regardless of the quantity of work performed in a given time. When this adjustment has been effected, it is probable that the index readings on the scale will be found to deviate more or less from the required decimal subdivisions of the rider weight.

A few sentences will elucidate the details of this final adjustment of the beam. By screwing up the ball, over the centre of the beam, we bring about two results:—

1. We raise the centre of gravity of the beam; and 2. As the ball is at best only an approximation to a true and uniformly dense sphere revolving on a vertical axis, by its revolution we displace, in some degree, the centre of gravity, in a direction other than the vertical. After screwing up or lowering the ball, the balance of the arms of the beam is found to be disturbed, and it becomes necessary to restore equilibrium by adjustment of the tongue. The tongue should be movable in azimuth on a plain cylindrical pin, without rising or falling on a screw-thread.

We may raise the ball until the balance becomes unstable, or we may lower the ball and consequently lower the centre of gravity of the beam until stability (disturbed by raising the ball) is fully restored. But when we require the greatest sensibility consistent with stability, we must, by a series of trials, bring the centre of gravity to a position a very little below the point upon which the beam oscillates (the centre knife-edge).

In the practice of this latter adjustment it will greatly assist operations to paint a small neat black dot on the equator of the ball, so as to be able by means of this mark to heighten or lower the ball with certainty a known number of threads of the screw, or, if necessary, any subdivision, as one half or a quarter of a turn.

These preliminary adjustments effected, the balance is to be loaded with the full load employed in the actual work, for example, with ten grains in each pan ; and by means of the rider-weight, the two sides are to be brought into exact equilibrium. Ascertain critically the justness of the equipoise, then move the rider so as to make one side of the beam ·005 of a grain heavier than the other side, and now observe, by aid of the seconds hand of a watch, the time required for the oscillations of the loaded beam ; observe, also, how many divisions of the index are equivalent to the extra load of ·005 of a grain. I will suppose that in this trial repeated experiments show that with the loaded pans for this weight of ·005 of a grain the needle sweeps from zero across two divisions of the scale, returning again to zero, and that the vibration is more than sufficiently rapid for our work. We now make a second trial : the ball is raised by two revolutions on the screw, the equilibrium of the loaded beam is adjusted by altering the position of the rider until the needle sweeps over an equal space on each side of the zero mark of the scale, and now, by moving the rider so as to be equal to an added weight of ·005 of a grain, we again try the time of oscillation and sensitiveness of the balance : the oscillations have become less rapid in consequence of the raising the centre of gravity of the beam, and the beam has at the same time become more sensitive, the ·005 of a grain being now represented by a larger sweep of the needle.

But after two or more trials of this kind we not only arrive at a nicer and still nicer adjustment of the sensitiveness and time of oscillation, but the comparison of our results affords a valuation of the thread of the screw upon which the ball is raised and depressed, as a means of adjusting with certainty the performance of the beam ; each revolution of the ball, raising it by the width of one thread, is found to retard the oscillation by a certain fraction of a second, and to increase its sensitiveness by a certain fraction of a division of the index-scale per ·001 of a grain added.

Patient and careful trials of the kind will enable us to adjust the balance so as to ensure the greatest sensitiveness compatible with its weight and workmanship, or we may compound between sensitiveness and rapidity, sacrificing the former in some degree, so as to secure a speed suitable to the quantity of work which is demanded in a given time.

Chemical balances of the best construction are known to indicate the millionth part of the load, that is to say, with 1000 grains in each pan the index will move over one division of the scale for ·001 of a grain added. With the assay balance, with 10 grains in each pan, if ·001 of a grain added is represented by one division of the scale, the sensitiveness falls far short of that of the larger chemical balance; instead of one-millionth, the quantity indicated is one ten-thousandth of the load; it is one hundred times less sensitive than the former, although in each case ·001 of a grain is indicated by one division of the scale. The oscillations, however, are quicker in the case of the assay balance.

Each individual assay balance will have its own degree of sensitiveness when adjusted for the slowest speed, or its own lesser degree of sensitiveness when adjusted for a given rapid working speed; and by lowering and heightening its centre of gravity, we may attain any combination of speed and sensitiveness, gaining in the one while we lose in the other, between these limits; but we are with each particular assay balance, bound within these limits of performance of the special instrument. Thus, if we have two assay beams, without radical defects, but of different make and weight, it will be found that their performances will differ; one will prove inferior to the other. If the inferior beam be adjusted to the same degree of sensitiveness as the better constructed beam, it will take a longer time for its oscillations; or if it be adjusted to oscillate in the same time as the superior beam, it will then fall short in sensitiveness.

But the knife-edges of the best balances, whether made of steel or agate, wear and become blunted during use, and the performance is, from this particular cause, gradually deteriorated. A large part of the keeping the balances in repair consists in the reparation, from time to time, of the knife-edges, and the readjustment of them in position in the beam. But between the time when the knife-edges are sensibly perfect and when they require the instrument maker's attention there is of course a small progressive wear and alteration of them, with consequent deterioration of the performance of the beam; the value of each degree of the index scale becoming from time to time a larger weight. These small progressive differences, within certain limits, may be obviated by adjustment of the ball; but when we have thus restored the sensitiveness of the beam we have thereby added to the time required for each weighing : the beam will oscillate more slowly. A better arrangement is that in which a series of scales, any one of which may be easily and quickly slipped into position under the index, is employed. The ordinary scale divides the full sweep of the index into twenty equal divisions, ten on each side of the zero point. If, now, we provide a series of five other scales in which smaller arcs are divided into twenty divisions, ten on each side of the zero point, we can from time to time substitute one or other of these scales for that originally in use, which latter, for distinction, I will call the ordinary scale. When the ordinary scale is replaced by one of these scales, we can weigh with the same speed, and virtually the same sensitiveness of the beam, and with no other disadvantage than such as may belong to a scale of somewhat closer divisions.

In these proposed supplementary scales ten divisions on each side of the zero mark are respectively equal to the following proportions of the ordinary scale.

In scale No.	2, 10	divisions	= an arc of	9	divisions	on No. 1,	the ordinary	scale
,,	3, 10	,,	= ,,	8	,,	,,		,,
,,	4, 10	,,	= ,,	7	,,	,,		,,
,,	5, 10	,,	= ,,	6	,,	,,		,,
,,	6, 10	,,	= ,,	5	,,	,,		,,

and with this series we can preserve the decimal value of the index readings until the sensitiveness of the beam has diminished by one half. The following example will illustrate the way in which these scales are brought into use:— For some time after the new beam is employed, no measureable diminution of sensitiveness can be observed ; but eventually the knife-edges become a little impaired, and when critically tried it is found that for ·005 of a grain the index sweeps only $4\frac{1}{2}$ divisions of scale No. 1 ; this is equivalent to sweeping 9 divisions for ·01 of a grain, and we can now readily compensate this diminished sensitiveness by replacing scale No. 1 by scale No. 2, in which the arc equal to nine divisions of scale 1 is divided into ten divisions. We may from time to time thus change the scales until the instrument has deteriorated in sensibility by one-half, when scale 6 will be used. A little consideration will make obvious that the series of six scales will cover all possible cases of wear between these wide limits. They provide ample and ready means of adjusting the value of the index readings, without modifying the speed of the weighing, and the instrument maker can be resorted to for keeping up the absolute sensitiveness of the balance as often as the quality of the work demands, just as under ordinary circumstances when these shifting scales are not employed. The method of using these shifting scales, indeed, is intended for obtaining more accurate readings of the index in decimal subdivisions of the weight employed as the assay pound, and not in any manner to supersede the necessary renovation and adjustment of the knife-edges by the instrument maker. It may be stated that the proposition of movable scales is one which has already been put into practice with complete and satisfactory results.*

Another form of these shifting scales has been conceived, but has not hitherto been put into actual use ; it seems to promise special facilities for adjusting the index readings to even a greater nicety than that belonging to the series of flat scales above described. Instead of a series of interchangeable flat scales, a small ivory reel, revolving on a horizontal axis, and retained in any position by a small spring, is fixed between the pillars of the balance support, immediately under the point of the index. The curve of the sides of this reel corresponds to the arc described by the point of the index, and around this curved surface, 72° apart, are inscribed the scales corresponding to Nos. 1 to 5 of the above described series of flat scales. The scale agreeing with No. 6 of that series is engraved in contact with scale No. 1, or that which divides the full arc swept by the index into 10 degrees on each side of the zero point ; the ten divisions of No. 6 exactly corresponding with five divisions of No. 1. A series of diverging or scroll lines connects these several scales, and in adjusting this revolving index scale it will be merely necessary to turn it round until that part, of which five divisions are found to be exactly equal to ·005 of a grain, is immediately under the index point.

But there are other points concerning the performance of the balance beam which are of great practical significance. If a beam, after careful adjustment, is exposed to change of temperature, its metallic constituent parts become altered in dimensions by expansion or contraction, and, as change of

* These shifting scales were made for the writer many years since, by Mr. L. Oertling, of London, who contrived them as a substitute for the proposed reel, as it is described in the following paragraph.

temperature in our apartments is the rule rather than the exception, the balance-beam is to be regarded in the light of a body constantly undergoing fluctuations in its size. We take the best precautions practicable under the circumstances, and we find that we are still unable wholly to counteract the influence of this cause upon the equilibrium of the beam; the effect of heated walls, stoves, &c., are among the causes which bring about unequal heating, and therefore unequal expansion of the arms of the balance; and it is only in a chamber sunk in the earth to the depth of approximate constant temperature that we can hope to escape from them, and it need hardly be added that such subterranean arrangements are incompatible with the conditions under which the ordinary assay of bullion is conducted.

But if a balance-beam adjusted at 60° Fahr. were slowly and equally raised in temperature to 90° Fahr., would all its parts remain so far just in their proportions as to retain accurately for the instrument, at this higher temperature, its original equilibrium and sensitiveness? It cannot be said that this would follow. The following extract from Professor W. H. Miller's elaborate memoir on the construction of the new imperial pound, in the Transactions of the Royal Society of London, 1856, is conclusive on this point:—

"In the course of making the preliminary observations some peculiarities of the instrument were discovered, which, though they probably exist in other balances, do not appear to have been hitherto noticed. One of these is that the expansion of one arm by heat, the left in the present case, is a little greater than that of the other arm. Hence, when the weights in the two pans are nearly equal and of equal volume, the reading of the scale in the position of equilibrium diminishes as the temperature of the beam increases. Another is, that the sensibility of the balance, as measured by the number of parts of the scale, equivalent to a given weight, was found to diminish with an increase of temperature. The cause of this is obvious. The beam being of bronze and the knife edges of steel, the balance-beam becomes an over-compensated pendulum, and an increase of temperature increases the distance between the middle knife-edge and the centre of gravity of the beam and weights, supposing the latter concentrated in the extreme knife-edges. Possibly, also, the flexure of the beam may increase with the temperature, or the mean expansion of the upper bar of the beam may be greater than that of the under bar. The variation of the sensibility of the balance is so large that it is necessary to determine the weight equivalent to a given number of parts of the scale for each set of observations, except in cases when the temperature is very nearly the same."

Between 60° and 87° Fahr. the expansion of each arm of a 10 in. balance is 14 ten-thousandths of an inch; if, for example, one arm of a balance were thus expanded, the opposite arm remaining of its original length; in that case, as the load multiplied into the length of arm is equal to the opposite load multiplied into the length of its arm, it follows that ten grains on the elongated arm would balance ten grains and ·003 of a grain on the opposite shorter arm. But although ·003 of a grain is a minute quantity regarded in the individual sense of so much gold, it is far from insignificant regarded in relation to the ten grains representing the mass assayed. Three ten-thousandths of a million sterling is no less than £300, and although it is not pretended that any inequality of the length of the arms at all approaching this proportion could occur through inequality of temperature or inequality of the coefficients of expansion in the mass of metal of which the beam consists, it at least shows that very small differences, due either to molecular constitution of the material of which the beam is made, or to inaccurate workmanship, can sensibly affect the results, and Dr. Miller's observations teach us that differences due to such causes actually exist in a measurable amount.

The adjustment of the centre and exterior knife-edges, even when the greatest care and skill are observed, is, at best, no more than a very close approximation to accuracy; with this closest approach properly ensured for one temperature, we are not to expect that it will obtain with certainty at another. If our desire is that of obtaining, under the limiting conditions of rapid execution of the work, &c. (which always belong to the bullion assay), the utmost accuracy of result, in this case it would appear that our attention should be devoted especially to the accuracy of the weights, and to such a system of work as will adopt all the reliable efficiency of the balance, at the same time counteracting the mixed and variable defects of the kind already mentioned. The modes of "double weighing," those of Borda and Gauss, are examples of methods by which a comparison of two ponderable bodies is effected in such a manner as to eliminate the errors proper to the balance itself.

In Borda's method :—The weights to be compared may be distinguished as Nos. 1 and 2. We counterpoise the heavier of the two weights by shot in the opposite pan ; we now substitute for weight No. 1 that marked No. 2, and add to the latter small fractional weights until an equipoise is established. The weights added show how much No. 1 is heavier than No. 2, and the result thus obtained is quite independent of inequality of the arms of the beam.

In Gauss' method :—The weights are placed in the opposite pans and the difference noted ; the pans with weights are now reversed on the beam, and the difference again noted ; the mean of these differences is the real difference of the weights in air, independent of any inequality of the arms of the balance.

These examples of methods actually employed whenever rigid determinations of weight are the object, show, beyond question, that with balances rendered sensitive by lightness and judicious distribution of metal, and by sharpness and true position of the knife-edges, the accuracy of our work will depend less on the accuracy of construction of the beam itself than on the accuracy of the weights, and that a method involving the principle of double weighing and depending especially on the accuracy of the weights is the one at present to be sought for as likely to lead to a nearer and more uniform approach to accuracy of results.

In proposing a mode of assay which involves the principles of double weighing, I wish to explain that although the method has been the subject of actual experiment, it is yet quite new in my hands ; I venture to describe it in the sense of a proposition, the adoption of which into daily practice must depend upon its ultimate proved merits as compared with the routine of weighing at present in use.

I will now make a short explanation concerning the assayer's weights, those employed at the present time. Let us take the case in which the assay is made on 10 grains of each sample, the weight representing this amount taken for trial, is what is commonly called the " assay pound." Whatever proportion of pure gold this assay pound of the sample is found to contain, such a proportion will the original bar, from which the assay piece has been cut, contain : all results being expressed according to a decimal notation.

Then, for this method the assay weights consist of:—

10 grains and its subdivisions	in grains.	
1 ,, ,, ,,	in tenths of a grain.	
·1 ,, ,, ,,	in hundredths of a grain.	

and a rider of platinum or gilt silver wire carried by a lever which slides parallel to the upper edge of the beam, permitting the rider to be placed on any point of the divided beam, or to be lifted off the beam altogether. This rider, according to its position on the beam, represents thousandths of a grain from ·001 to ·100, or its full weight when placed in the pan, as will be obvious when we consider that the beam is divided into 100 parts on each arm, and that the rider weighs one-tenth of a grain. But because the ten-grain weight, the assayer's pound, is regarded as unity, and all the smaller weights are regarded as decimal fractions of unity, they are marked, conformably to this view, as follows:—

The 10 grain weight or pound is marked	1·
The grain subdivisions are marked respectively	·6 ·3 ·2 and ·1
The subdivisions of the grain ,, ,,	·06 ·03 ·02 and ·01

The rider, weighing one-tenth of a grain, and used on the principle of the steelyard, by placing it on one or other of the divisions of the beam, furnishes all subdivisions of unity from ·01 to ·0001.

In assay balances, as they are now made, a few subdivisions of the beam, namely, those nearest the outer knife-edges, are wanting, a deficiency resulting from the particular pattern of the beam ends. This incompleteness of the divided beam is certainly not of an insurmountable character, should complete subdivision of the beam be required; and that this complete subdivision is wanted for the routine about to be proposed will presently become apparent.

But besides the weights just described, a second series is commonly used. Taking the unit (or pound) weight, representing each bulk or bar of gold, and submitting this quantity to the operations of the assay, and thus obtaining, for each sample, the pure gold obtained in it; the weight of this pure gold product as ascertained with the above-described weights, expresses decimally the fineness of the particular sample, and enables us to value the bar or parcel of gold which it represents, as far as gold contents are concerned.

For expedition and accuracy it is found best to have, in addition to the above-described series of weights, a second set, such as will enable us to weigh these fine gold educts, or cornets as they are called, with always a single weight in the pan, and with the rider on the beam. Twenty weights are required, they range according to the decimal notation already described from ·80 to ·99 (from eight grains to nine and nine-tenth grains actual weight). If the cornet weighs ·9843 with the weight ·98 in the pan, and the rider on the 42nd division of the beam, we seek the additional ·0001 by the sweep of the index, and thus arrive at the weight of the cornet ; *the accuracy of the weighment, however, depending more or less on those points which concern the accuracy of the beam,* to which reference has already been made.

One final explanation will prepare the way for what I have to propose in amendment of the above-described method. First, it is to be understood that for economy of time, and for other obvious reasons, the proper weight of each sample to be assayed is first prepared with tolerably close approximation, by an assistant, and the assay pieces thus prepared are finally weighed and adjusted by the assayer. Secondly, it should be remembered that the cost or care required for the preparation of weights of extreme accuracy, even though the weights be multiplied in number, is a matter of quite minor importance as long as the utmost accuracy of the work is thereby maintained.

I will now proceed to a concise description of the proposed method. First, as to the balance suitable for this modified procedure: it is essential that it be light in the beam, simple in construction, rigid, with sharp and hard knife-edges, which must be truly set at right angles to the length of the arms. These qualifications are essential ; they are commonly to be found in the best description of assay balances, but certain others commonly attempted in the best assay balances are non-essentials for the particular method about to be described. It is not necessary that there shall be absolute or even approximate equality of the two arms, but prime importance is attached to those requisites which determine rapidity of oscillation and sensitiveness. Only one minor alteration of the pattern of the common assay beam is proposed, that, namely, which concerns the range of the rider. It is suggested that an offshoot from the beam for supporting the latter, as shown in the illustration, be formed, so as to become rigidly a part of the beam and allow the rider to rest over the outer knife-edge, or on any position intermediate between that and the centre knife-edge of the beam. The range of the rider thus includes the whole extent of one arm of the balance.

In adapting this piece to the assay beam of the usual pattern it will be found necessary to set the divided upper edge of it a little out of the vertical plane, which equally divides the beam from end to end, and to incline it towards the back of the lantern, so as to accommodate its position to the sweep of the lever by which the rider is lifted (this is shown in the sketch attached to the present paper). The same lever will then serve for placing the rider on any part of the beam itself, or on this auxiliary piece.

Besides the weights already enumerated, I propose an additional series of twenty small weights, of gold or platinum, weighing actually one-tenth of a grain, two-tenths of a grain, and so by regular progression of one-tenth of a grain, up to one and nine-tenths grains; and at the outset we must convince ourselves that these weights are as accurate as care and skill can make them, and then I think it can be shown that with them we shall be able to perform all the work of the assay independently of the relative lengths of the arms of the balance, and that fortified by the series of weights ·99 to ·8 (as above described) in the position of weights of reference, they will enable us to eliminate one of the chief sources of error in the assay, that, namely, which results from the wearing of the weights.

But the use of this series of weights which I now propose, involves this principle, namely, that the load of the balance is in all cases constant (the pound of ten grains), a condition which is also highly favourable to uniform and accurate results. We adopt the conjoint advantages of double weighing and a constant load.

We adjust our balance so as to effect an equipoise with the pound in the right-hand pan, and removing this pound we weigh in its place and adjust to equality with it each of our samples to be assayed. The assay is conducted through its several processes in the usual manner, and the resulting gold cornets are each in succession placed in the pan of the balance. What the trial piece has lost is base metal; what is retained of its ponderable substance, subject however to the usual variable correction for surcharge,* is pure gold.

* For the general reader, it is explained that the technical term "surcharge," used in its broadest sense, is understood to mean the correction which it is necessary to make in order to reduce the weight of the cornet to that of the pure gold which it represents; there is loss of gold on the cupel

The weight which it is necessary to add to the cornet in the pan of the balance so as to restore equilibrium, represents what it has lost and what was alloy, and *we may mark the weight thus added not with its own real weight, but with what is more convenient, namely, its difference from the weight of the pound or unity.* If ten grains or unity has lost during the assay one grain, because it originally contained that amount of silver, copper, or other foreign metals, the cornet, when placed in the pan of the balance, will require the addition to it of one grain weight to effect an equipoise, and this one grain weight, by establishing an equipoise, will signify that the cornet weighs nine grains, and that the sample assayed has a fineness of ·9.

This routine would possess the anticipated advantages in all cases of gold bullion of finenesses between ·8 and 1·0, excepting that the fractional parts, as determined by the use of the rider, have as yet no solution by its means; the use of the rider, so valuable in all appeals to the balance, need not be excluded from this method, as I hope now to explain by a more detailed description of the proposed method.

First, I will describe the new set of weights: they consist of a progressive series from ·1 grain to 1·9 grains, gradually rising through the series by tenth of a grain differences, and, for reasons to be presently explained, they are each marked as shown in the following table: —

TABLE OF NEW SERIES OF COMPENSATING WEIGHTS.

Real amount of weight	·1 gr.	·2 gr.	·3 gr.	·4 gr.	·5 gr.
Mark - -	·98	·97	·96	·95	·94
Real amount of weight	·6 gr.	·7 gr.	·8 gr.	·9 gr.	1·0 gr.
Mark - -	·93	·92	·91	·9	·89
Real amount of weight	1·1 gr.	1·2 gr.	1·3 gr.	1·4 gr.	1·5 gr.
Mark - -	·88	·87	·86	·85	·84
Real amount of weight	1·6 gr.	1·7 gr.	1·8 gr.	1·9 gr.	
Mark - -	·83	·82	·81	·8	

There is also to be provided a rider of the real weight of ·1 grain, as usual.

All these weights, in addition to the pound of 10 grains, are to be arranged on the right hand side of the balance,

by volatilization and absorption, and there is increase of weight of the cornet by a small residue of silver which the parting operation has left in it, and the difference of these two opposite errors constitutes the surcharge.

and the rider is to be placed on the slider of the same side ready for use. Before commencing work, we place the pound weight in the pan, and adjust, if necessary, the tongue of the beam so as to effect an equipoise. We remove the 10-grain weight and substitute, in order, our trial pieces; as we now effect an equipoise with each of these, we are sure we obtain a weight of each exactly the same as that of the 10-grain weight, and quite irrespective of the relative length of the two arms of the balance, and when we have cupelled and parted these, and obtained their gold in the form of cornets, we place these in succession in the pan of the balance and add weights until an equipoise is effected. We add weights and we also use the rider, *placing the latter always first over the end knife-edge and moving it progressively towards the centre of the beam.* We read the divisions of the beam in an order inverse to that employed in the common mode of weighing. When the rider is placed on the mark immediately over the end knife-edge, it is read ·0000 of unity; if placed over the centre knife-edge, or what is the same thing, lifted off the beam altogether, it is read ·0100 of unity, and for intermediate positions, on the first of the nine major divisions between the centre and end knife-edges (dividing the arm into ten equal parts), it is read on that nearest the end knife-edge .0010, and on the others as we progress ·0020, ·0030, to ·0090, the major division nearest the centre of the beam; for in sliding the rider-weight towards the centre of the beam we are in reality taking off weight, which act implies a corresponding amount of gold in the cornet. Whether in the pan or on the beam, our weights placed so as to effect an equipoise, make up with the weight of the cornet exactly ten grains; they are in this sense the complement to the weight of the cornet, and the mode of marking the weights and reading the position of the rider, is that which instead of regarding the real value of the weight itself, indicates always the amount of which it is the complement. Thus, to suppose a case, with cornets of the following weights, an equipoise will in each case be obtained by the addition of a single weight as marked, and by shifting the rider to the position indicated in the table.

FINENESS INDICATED.									LOAD.					
Real Weight of Cornet.	Mark of Weight added.		Position of Rider indicates		Fineness therefore indicated.		Real Weight of Cornet.		Real value of Weight added.		Virtual Weight of Rider.		Total Load. Cornet, Weight, and Rider.
							Grains.		Grain.		grain.		Grs.
·9433	·94	+	·0033	=	·9433		9·433	+	·500	+	·067	=	10
·9999	nil.	+	·0099	=	·9999		9·999	+	nil.	+	·001	=	10
·9172	·91	+	·0072	=	·9172		9·172	+	·800	+	·028	=	10
·8426	·84	+	·0026	=	·8426		8·426	+	1·500	+	·074	=	10
·8016	·80	+	·0016	=	·8016		8·016	+	1·900	+	·084	=	10
·9652	·96	+	·0052	=	·9652		9·652	+	·300	+	·048	=	10
·9789	·97	+	·0089	=	·9789		9·789	+	·200	+	·011	=	10

The notation involved in this method is as easy as that of the old practice, the index readings are also as facile. Thus, suppose a cornet weighing ·9958, and placing it in the pan without any other weight, we now put the rider on the division marked 60, this would read ·9960 ; but as the beam carries now a real weight of only 9·958 + ·040 = 9·998, it will show two divisions of the scale light on the right hand pan or cornet side ; we may therefore either move the rider back to the ·0058, when the beam will have its full load of ·9958 + ·0042 = 10 grains, making an equipoise, or we may compute this ·9960 — ·0002 = ·9958; for with any given reading of the weights what falls short of an equipoise is so much deficiency of the cornet below the fineness indicated, and must be deducted from the reading to arrive at the real weight of the cornet. Conversely with any given reading of the weights, what is shown by the index to be in excess of an equipoise, is so much excess weight of the cornet beyond the fineness indicated by the weights, and must be added to the reading of the weights for arriving at the real weight of the cornet.

The greater part of Mint gold assay work, in Victoria at least, concerns gold varying in fineness between ·8 and 1·0, or pure gold, for which the series of weights above recommended is suitable. For the comparatively rare occasions presenting gold of a fineness lower than ·8 the ordinary grain weights could be used as by the old method, but in the sense of complements to the weight of the cornet ; say that with the cornet in the pan we are obliged to place three grains, and one grain and ·4 of a grain, and the rider on the ·0043 to form an equipoise less two divisions of the index scale: then we have 4·4 grains which, deducted from 9·9 grains = 5·5 grains, and ·0043 — ·0002 = ·0041 indicated by the rider. The fineness thus indicated is obviously ·5541: or a small card of reference might be used for showing at a glance the complementary value of any combination of grain weights and tenths of a grain in these extreme cases.

I will now endeavour to enumerate the special advantages of this method, premising that weights as much in use as those of the bullion assayer, even when lifted with ivory or horn forceps, are liable to wear, and that wear of the weights is a dangerous source of error.

1. The proposed method is in all respects equivalent to double weighing; it is independent of the relative lengths of the arms of the beam, whether arising from original imperfect workmanship or from permanent molecular alteration, or from daily vicissitude.

2. The weighments are all made with an uniform load, which satisfies another condition of accuracy more exactly than the common method, the sensitiveness of the beam varying with the load.

3. Substituting the proposed new series of weights for the old (for those described on page 103) we devote the latter henceforth to the purposes of reference, upon which aplication a few sentences may now be bestowed:—

With the rider over end knife-edge, each weight of the new series added to that bearing the same mark in the old series should effect an equipoise, thus:—

	Old Series	+	New Series	+	Rider	= 10 grains.
Mark.	Real weight.		Real weight.			
·99	9·9 grains	+	0	+	·1 grain	= 10 grains.
·98	9·8 „	+	·1	+	·1 „	= 10 „
·97	9·7 „	+	·2	+	·1 „	= 10 „

and so on. And for further verification of the new weights, interchanges, too obvious to require explanation, can be employed. Now, supposing a weight of the new series to have worn in use, say, for example, that the weight marked ·97 has become a thousandth of a grain short of its real weight (·2 of a grain) when just; this becomes evident on placing it in the pan with the ·97 reference weight, the rider also in the pan or over the end knife-edge; this combination of weights will fall short of an exact equipoise by ·001 of a grain. To make a fresh weight in place of the defective one, we have only to fashion and reduce a piece of platinum or gold until with the old ·97 weight and the rider it effects an equipoise.